U. S. DEPARTMENT OF COMMERCE
JESSE H. JONES, Secretary

COAST AND GEODETIC SURVEY
LEO OTIS COLBERT, Director

Special Publication No. 158
Revised (1940) edition

BILBY STEEL TOWER FOR TRIANGULATION

BY

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Signalman (retired)

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1940

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National Oceanic and Atmospheric Administration

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January 1, 2006

FOREWORD (1940 EDITION)

The use of the portable steel tower for triangulation surveys has contributed toward marked economy and efficiency of operation of the field units. A wooden tower 75 feet in height would cost about $120 for lumber alone and take a crew of 6 men at least 3 days to erect. Although the initial cost of a steel tower is higher than the cost of materials for a wooden tower, the steel structure can be erected in about 5 hours and may be dismantled and used time and time again, a characteristic which does not pertain to the wooden tower. The steel towers have been built to a height of 156 feet in 1 day's time. To erect a wooden tower to this height would take at least a week with the usual building crew.

The portable steel tower has been in use each year since 1927. Its use has made it possible to carry on triangulation in flat country covered with high timber. Without it, control surveys in such country would be extended by traverse, a more expensive operation and one not subject to the checks in resulting data which pertain to triangulation.

Since the original edition of this publication appeared in 1929, several minor changes have been made in the design of the steel tower. Descriptions of these changes are incorporated in the present text. J. S. Bilby, the author of the original manuscript, retired from the service of the Coast and Geodetic Survey in 1937 after 53 years of service. The present edition has been revised by personnel attached to the Division of Geodesy, United States Coast and Geodetic Survey.

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BILBY STEEL TOWER FOR TRIANGULATION

By JASPER S. BILBY, *Signalman (retired), United States Coast and Geodetic Survey*

PURPOSE OF TRIANGULATION TOWERS

In many regions it is not possible to select stations for a scheme of triangulation and have the stations intervisible from the ground, as trees, buildings, and other objects obstruct the line of vision between adjacent points. On geodetic surveys, covering wide expanses of territory, the curvature of the earth must also be taken into account. Towers are, therefore, necessary to elevate above intervening obstructions the observer and his instrument at one station and the signal lamp or object on which he makes his observations at the distant station.

A complete triangulation tower is a combination of an inner and an outer structure mutually independent; that is, the two structures must not touch at any point. The service required of a tower, when two observing parties are working at the same time at different stations in the same figure is, briefly, that the outer structure must support the observer and the tent which protects him and his instrument from the sun and wind and, at the same time and without interference with the observer or his work, support a light keeper and the lamp or heliotrope upon which the other observer is sighting. The inner structure must support the instrument with such stability that, except in very strong winds, its motion in azimuth will never be so rapid nor so great as to affect seriously the accuracy of the measured angles and that its disturbance in level will never be so irregular as to inconvenience the observer by making frequent adjustments necessary.

Previous to 1927 wooden structures were used exclusively for triangulation towers, but since then the cost of lumber and labor has become so high as almost to prohibit their use. (See fig. 1.)

STEEL TOWERS

During the winter of 1926 preliminary specifications were prepared by the writer for a steel tower that could repeatedly be erected, taken down, and moved by truck to a new station. Later, he took the preliminary plans to the factory of the Aermotor Co. in Chicago, where, with the aid of their designing engineers and after several tests and modifications, a complete tower was constructed and erected.

Three essential requirements have to be satisfied to make the steel tower a success: First, the tower must have great rigidity and stability against vibration and against twist in azimuth; second, the tower must be so constructed that it can be readily erected and taken down; third, the total weight of a completed tower should preferably be light enough that a single moderate-sized truck can transport it from station to station.

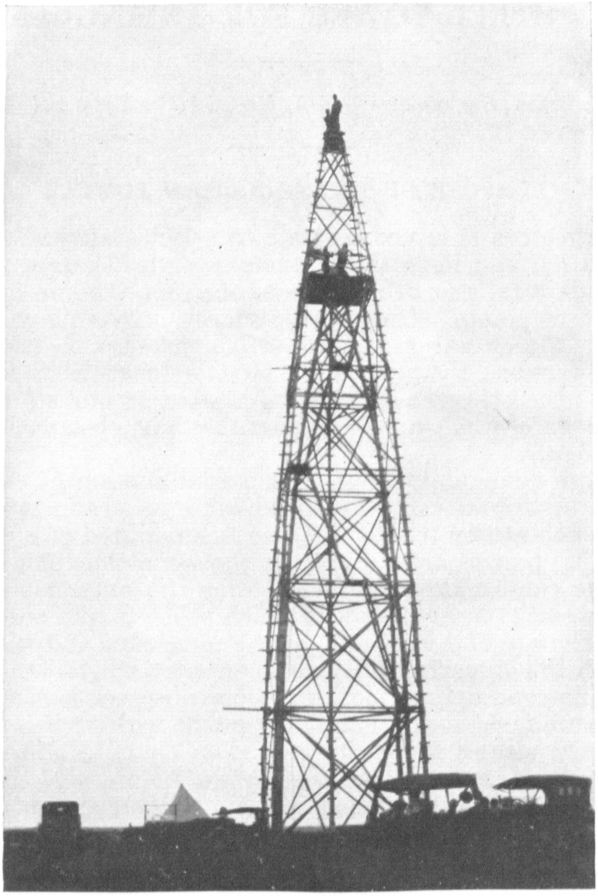

FIGURE 1.—Seventy-five-foot wooden tower at McDowell triangulation station, Texas.

After the first tower had been completed and erected at the factory a final test was made which showed clearly the degree of rigidity and elasticity which could be expected in the towers. This test made it clear that the steel tower would satisfy every requirement. The following plans, specifications, and instructions to bidders were drawn for the additional towers and forwarded to the Director of the United States Coast and Geodetic Survey, who gave the structure the official designation of "Bilby Steel Tower."

SPECIFICATIONS FOR BILBY STEEL TOWER

The attached detailed drawing shows a design sketch of the Bilby tower, complete as to detail. The manufacturer must follow these specifications and the details shown on blue print without any deviation therefrom.

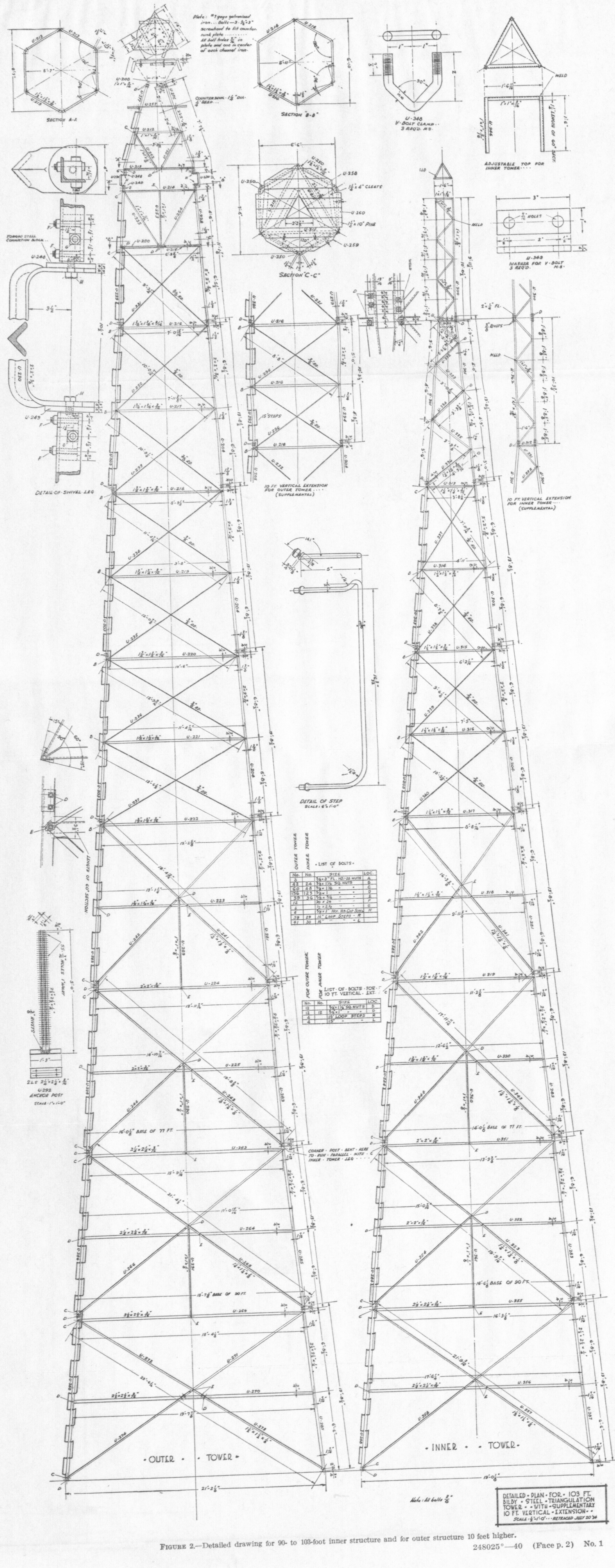

FIGURE 2.—Detailed drawing for 90- to 103-foot inner structure and for outer structure 10 feet higher.

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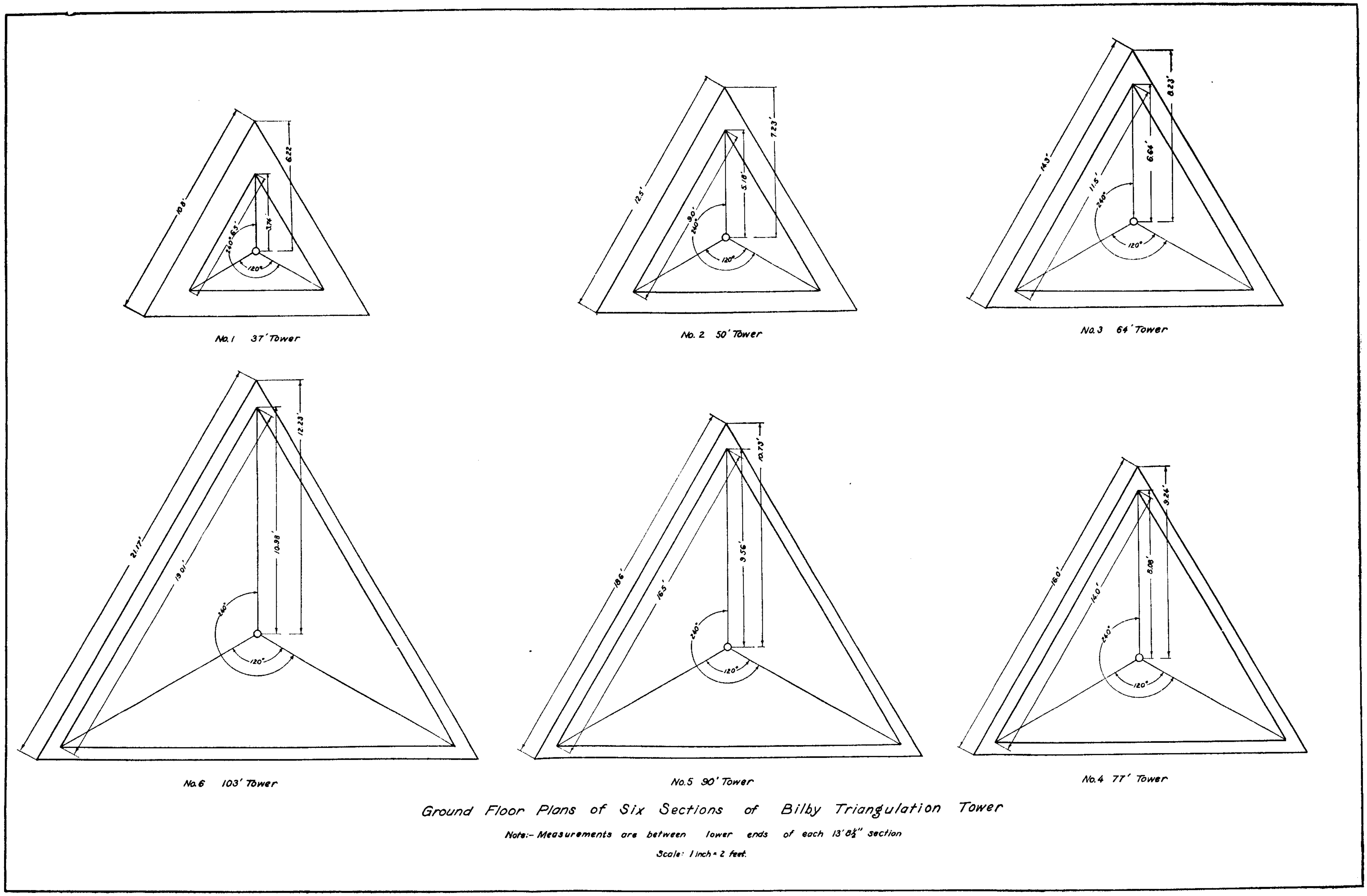

FIGURE 3a.—Ground plans for 37-, 50-, 64- , 77-, 90-, and 103-foot Bilby steel towers.

Both inner and outer towers are three-legged, as shown by figures 3a and 3b showing ground plan of tower at different heights. The outer tripod tower is changed to hexagonal shape at section *C–C*, as shown by sections *A–A*, *B–B*, and *C–C*.

All material of metal shall be of high-grade structural steel. All steel parts shall be galvanized in accordance with the best practice after all machining and welding is completed, and shall not be subject to flaking.

There must be furnished with each tower a diagram showing the size and the factory number of each of the pieces of the structure, including bolts, anchors, platforms, etc. The parts of the several towers must be interchangeable.

The sectional lengths of the outer and of the inner towers must be the same as shown on the attached drawing. The towers must be so constructed that one or more of the lowest sections can be omitted when the full height is not needed. Holes must be made in the tops of the anchor posts, as indicated in the sketch, in order that the tower may be adjusted in height on the anchor posts.

Ladder steps must be of the same type as shown on the blueprint, or of a type equally as strong. The steps will be used on one post of the inner tower and one post of the outer tower, as shown on figure 2.

Bands of paint, 8 to 10 inches in length, must be placed on all upright and diagonal pieces of the outer and inner towers. Blue paint will be used for the outer tower and red for the inner one. This will make it easy to separate the pieces belonging to the inner and outer structures. The bands will be placed at the top ends of the sections of the posts and near the left-hand end of the ties and diagonals, as viewed from outside the tower. The small blueprint attached indicates the parts of the members which are to be banded.

There must be furnished, with each tower, extra bolts to the extent of 20 percent for each size and length of bolt used on the inner and outer structures. A like amount of nuts for these bolts shall also be furnished.

For a lot of 10 or more towers there should be 6 anchors for each tower and 12 extra anchors. The extra anchors are to serve as replacements and also are for use by the forward building parties prior to the arrival at the station of the tower with the regular anchors.

There must be furnished with each lot of towers 12 suitable end wrenches to fit all bolts and nuts and also 3 good spike punches of sufficient length and size to clear holes and to spring parts together.

TESTS TO BE MET BY COMPLETED TOWER

INNER STRUCTURE

Horizontal displacement.—A horizontal pull of 400 pounds at top of inner structure must not displace the top by more than *one-half inch*.

Angular displacement.—A tangential horizontal pull of 50 pounds applied at the corner of the top of inner structure must not cause an angular displacement of the top of more than 1 minute of arc. This corresponds to a horizontal displacement of the corner of the structure with relation to the center of about *two-thousandths of an inch*.

A tangential horizontal pull of 50 pounds at the corner of the inner structure 23 feet below the top must not cause an angular displacement of the top of the structure of more than 50 seconds of arc.

Vibration.—A wind velocity of 20 miles per hour averaged over 1-minute intervals shall not cause the top of the inner structure to vibrate in azimuth more than 10 seconds of arc.

Semipermanent change in azimuth.—Gusts of wind of a velocity of 35 miles per hour or less shall not cause a semipermanent angular displacement of the top of the inner structure of more than 2 seconds of arc.

OUTER STRUCTURE

A horizontal pull of 500 pounds at center of side of outer structure at height of floor platform, the pull being applied through a bridle attached to two of the main posts, must not displace the outer structure horizontally by more than 3 inches nor cause the buckling of any member. The same pull applied to a corner post of the outer structure at the height of platform must not displace the top of the structure horizontally by more than 5 inches nor cause buckling of any member.

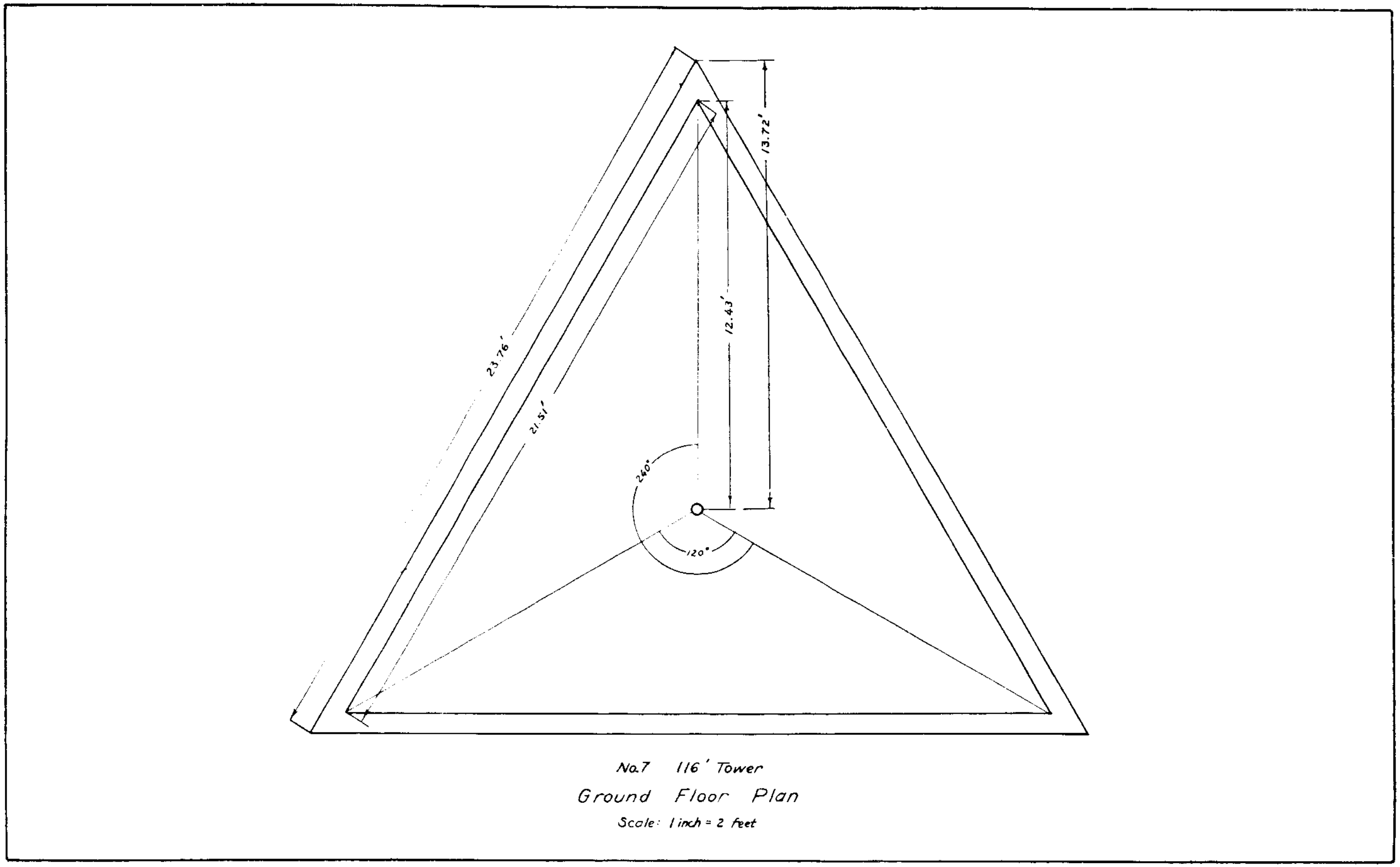

FIGURE 3b.—Ground plan for 116-foot Bilby steel tower.

DETAILED DRAWING FOR BILBY STEEL TOWER

Figure 2 gives detailed drawings for a 103-foot inner structure and a 113-foot outer structure, both of the tripod type. The drawings show one side of each structure and the manner in which the parts are assembled and bolted together. Bolts are used throughout on both structures, except at the top section of the inner one, which is welded and has an adjustable top secured with V-bolt clamps, which can be adjusted to the proper height for the observer. One post of each structure is fitted with steps, as shown in the drawing. Sections A–B, B–B, and C–C show the design of the frame of the outer structure for the observing tent and the observer's platform. Above this is the superstructure on which the lamp is mounted. The seat for the lightkeeper is 2 feet below the top of the superstructure.

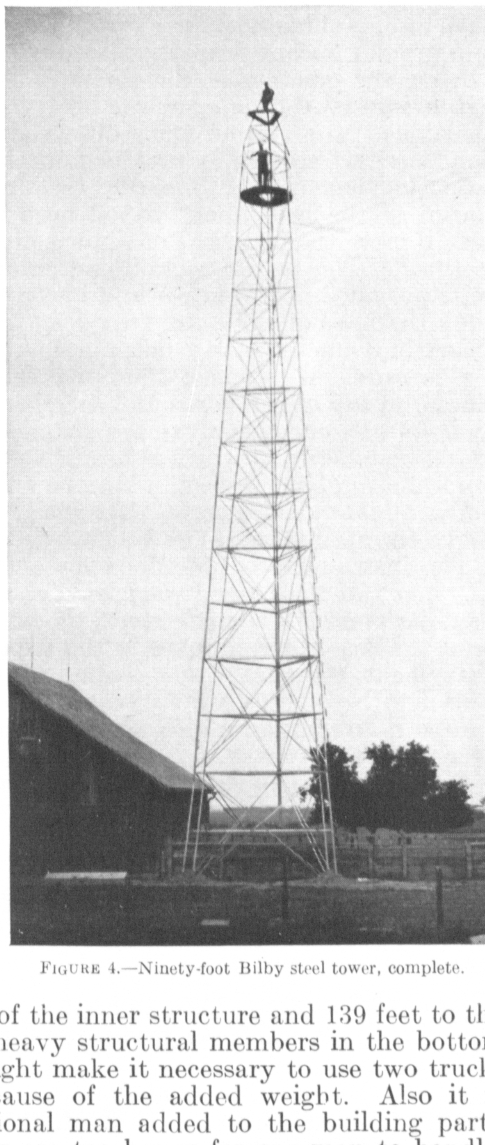

FIGURE 4.—Ninety-foot Bilby steel tower, complete.

Figure 4 shows a completed triangulation steel tower, consisting of an inner and outer tripod, separated from each other so that the inner one may not be affected by the observer's movements. The height of the inner tripod is 90 feet and of the outer one is 100 feet. The total weight of the complete tower, including anchors and anchor sills, is 5,270 pounds. The height of tower commonly in use is 103 feet for the inner structure and 113 feet for the outer one, a tower of this height weighing about 6,640 pounds.

Towers have been designed for a maximum height of 129 feet to the top of the inner structure and 139 feet to the top of the outer one. The heavy structural members in the bottom section of a tower of this height make it necessary to use two trucks to transport one tower because of the added weight. Also it is necessary to have an additional man added to the building party because the bottom members are too heavy for one man to handle. For these reasons the 129-foot structure is no longer used and the

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maximum height of a tower is now 116 feet to the top of the inner tower and 126 feet to the top of the outer tower.

After a tower has been erected, it is sometimes found that additional height is needed to clear intervening obstructions. Supplemental 10-foot vertical extensions for both the outer and inner towers may then be inserted in the section immediately below the observer's platform. As many as 4 or 5 of these supplemental sections may be inserted in the structure at this point. When several of these extensions are inserted, each of the three legs of each tripod should have an individual guy wire leading from the upper part of the tower to a ground anchor properly placed.

After the erection of the tower it may be found that one of the tripod legs of the outer tower obstructs the line of sight from the instrument to a station being observed. To take care of this condition a swivel section is provided in the outer leg which permits a radial movement of 3½ inches. Each outer tripod leg at the section abeam of the instrument tripod head has this arrangement so that even if more than one line of sight is obstructed, the condition can be rectified. This swivel section can easily be moved by loosening the bolts provided at the upper and lower ends of this member.

At the head of the outer tripod a 7-gage galvanized-iron plate, 15 inches in diameter with a hole one-fourth inch in diameter at its center, is provided to which the signal lamp is secured. This plate is placed on top of the horizontal members of the tripod and is secured by bolts to a narrow galvanized channel iron which is below the horizontal members and which is brought up tight against these members to form a rigid connection. Various bolt holes in this plate permit of sufficient lateral motion so that the center can be placed vertically above the station mark.

The instrument is placed on an aluminum tripod plate which is set on top of the inner tripod head and which is secured by bolts to a similar plate placed underneath the horizontal members of the tripod head. Three radial grooves in the tripod plate insure that when the instrument supports rest therein, the theodolite is symmetrically placed with respect to the center of the plate. Considerable lateral motion is provided for this plate so that it can be centered directly over the station mark.

Figures 3a and 3b show the ground plan for laying out the holes and setting the anchors for towers of different heights. The towers are designed so that from one to five of the lowest sections may be left out where it is not necessary to erect the tower to its full height. The measurements given on the ground plan correspond with sectional measurements on the tower.

WEIGHT OF MEMBERS IN BILBY STEEL TOWER

Weight of various sections of outer tower

Plan No.	Size (inches)[1]	Number of pieces	Length		Total length	Weight per foot	Total weight	Total weight by sections	Total weight of outer tower
			Ft.	*In.*	*Ft.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
U-218	1¾ x 1¾ x 3/16	3	8	10	26.5	2.2	58.3		
U-204, U-205	2 x 2 x 3/16	3	13	9	41.3	2.5	103.3		
U-233	⅜ rod	6	10	10	65.0	0.376	24.4		
U-217	1¾ x 1¾ x 3/16	3	8	0	24.0	2.2	52.7		
U-232	⅜ rod	6	10	4	62.0	0.376	23.3		
U-216	1¾ x 1¾ x 3/16	3	7	1	21.2	2.2	46.8		
U-279, U-280	2 x 2 x 3/16	3	11	2	33.5	2.5	83.5		
U-231	⅜ rod	6	9	6	57.0	0.376	21.4		
U-215	2 x 2 x 3/16	3	6	4	19.0	2.5	47.5		
U-250	1½ x 1½ x 3/16	3	7	6	22.5	1.8	40.5		
U-254, U-255	1 x 1 x ⅛	6	5	4	32.0	0.8	25.5		
U-253	1 x 1 x ⅛	3	4	6	13.5	0.8	10.8		
U-214	1½ x 1½ x 3/16	3	7	0	21.0	1.8	37.8		
U-278	2 x 2 x 3/16	3	1	8	5.0	2.5	12.5		
U-213	1½ x 1½ x 3/16	3	7	0	21.0	1.8	37.8		
U-276, U-277	2 x 2 x 3/16	3	7	8	23.0	2.5	57.5		
U-251, U-252	1 x 1 x ⅛	6	3	6	21.0	0.8	16.8		
U-212	1 x 1 x 3/16	3	3	10	11.5	1.2	13.8		
U-208	1 x 1 x 3/16	3	1	6	4.5	1.2	5.5		
Steps	⅜ round	20	2	4	46.7	0.376	17.5	737.2	
Weight of 25-foot section									737.2
U-292	2½ x 2½ x ¼	3	5	0	15.0	4.1	61.5		
U-292	2¼ x 2¼ x 3/16	3	3	0	9.0	2.8	25.2		
U-204, U-205	2 x 2 x 3/16	3	13	9	41.3	2.5	103.2		
U-234	⅜ rod	6	11	6	69.0	0.376	25.9		
U-235	⅜ rod	6	12	2	73.0	0.376	27.4		
U-219	1¾ x 1¾ x 3/16	3	9	10	29.4	2.2	64.6		
U-220	1¾ x 1¾ x 3/16	3	10	8	31.8	2.2	69.9		
U-204, U-205	2 x 2 x 3/16	3	13	9	41.3	2.5	103.2		
U-236	⅜ rod	6	13	0	78.0	0.376	28.6		
U-237	⅜ rod	6	13	9	82.6	0.376	31.0		
U-221	1¾ x 1¾ x 3/16	3	11	6	34.5	2.2	76.0		
U-222	1¾ x 1¾ x 3/16	3	12	4	36.9	2.2	81.0		
U-281, U-282	2 x 2 x ¼	3	13	9	41.3	3.2	132.1		
U-241, U-242	1¼ x 1¼ x ⅛	6	18	6	110.8	1.1	121.5		
U-289	1 x 1 x ⅛	3	7	6	22.5	0.8	18.0		
U-223	1¾ x 1¾ x 3/16	3	13	3	39.8	2.2	87.6		
U-224	2 x 2 x 3/16	3	14	0	42.0	2.5	105.0		
U-283, U-284	2¼ x 2¼ x ¼	3	13	9	41.3	3.7	153.0		
U-243, U-244	1¼ x 1¼ x ⅛	6	19	10	119.0	1.1	131.0		
U-290	1 x 1 x ⅛	3	7	6	22.8	0.8	18.3		
U-225	2 x 2 x 3/16	3	15	0	45.0	2.5	112.5		
Steps	⅜ round	40	2	4	93.2	0.376	35.0	1,611.5	
Weight of 77-foot section									2,349
U-263	2¼ x 2¼ x 3/16	3	16	3	48.7	2.8	136.0		
U-285, U-286	2¼ x 2¼ x ¼	3	13	9	41.3	3.7	153.0		
U-265, U-266	1¼ x 1¼ x ⅛	6	21	6	129.0	1.1	142.0		
U-291	1 x 1 x ⅛	3	7	6	22.5	0.8	18.0		
U-264	2¼ x 2¼ x 3/16	3	17	3	51.8	2.8	145.0		
Steps	⅜ round	10	2	4	23.0	0.376	8.6	602.6	
Weight of 90-foot section									2,951
U-269	2½ x 2½ x 3/16	3	18	9	56.2	3.1	174.0		
U-287, U-288	2½ x 2½ x ¼	3	13	9	41.3	4.1	169.5		
U-271, U-272, U-273, U-274	1½ x 1½ x ⅛	6	23	8	142.0	1.3	184.5		
U-270	2½ x 2½ x 3/16	3	19	10	59.5	3.1	184.5		
Steps	⅜ round	10	2	4	23.2	0.376	8.5	721.0	
Weight of 103-foot section									3,672

[1] The pieces are of angle iron except as indicated.

Weight of various sections of outer tower—Continued

Plan No.	Size (inches) [1]	Number of pieces	Length (Ft.)	Length (In.)	Total length	Weight per foot	Total weight	Total weight by sections	Total weight of outer tower
			Ft.	*In.*	*Ft.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
U-299	1 x 1 x ⅛	3	7	6	22.5	0.8	18.0		
U-287, U-288	2½ x 2½ x ¼	3	13	9	41.3	4.1	169.5		
U-298A, U-298B, U-298C, U-298D	1½ x 1½ x ⅛	6	25	10	155.0	1.3	200.8		
U-297A	3 x 3 x 3/16	3	21	0	63.0	3.7	233.0		
U-297B	3 x 3 x 3/16	3	22	4	67.0	3.7	238.0		
Steps	⅜ round	10	2	4	23.2	0.376	8.5	867.8	
Weight of 116-foot section									4,540
U-410	1 x 1 x ⅛	3	7	6	22.5	0.8	18.0		
U-400, U-401	3 x 3 x ¼	3	13	9	41.3	4.9	203.0		
U-406, U-407, U-408, U-409	1½ x 1½ x ⅛	6	28	0	168.0	1.3	219.0		
U-402, U-403	3½ x 3½ x ¼	3	24	0	72.0	5.9	425.0		
U-404, U-405	3½ x 3½ x ¼	3	25	4	76.0	5.9	418.0		
Steps	⅜ round	10	2	4	23.2	0.376	8.5	1,321.5	
Weight of 129-foot section									5,862

TOWER EXTENSION

Plan No.	Size (inches) [1]	Number of pieces	Length (Ft.)	Length (In.)	Total length	Weight per foot	Total weight	Total weight by sections	Total weight of outer tower
U-216	1¾ x 1¾ x 3/16	9	7	1	63.8	2.2	140.0		
U-294, U-295	2 x 2 x 3/16	3	10	4	31.0	2.5	77.5		
U-296	⅜ rod	12	8	10	106.0	0.376	39.8		
Steps	⅜ round	8	2	4	18.7	0.376	7.0	264.3	

Weight of various sections of inner tower

Plan No.	Size (inches) [1]	Number of pieces	Length (Ft.)	Length (In.)	Total length	Weight per foot	Total weight	Total weight by sections	Total weight of inner tower
			Ft.	*In.*	*Ft.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
U-313	1¼ x 1¼ x 3/16	3	3	9	11.2	1.5	16.9		
U-301	1¾ x 1¾ x 3/16	3	13	9	41.2	2.2	91.0		
U-336	1¾ x 1¾ x 3/16	3	4	4	13.0	2.2	28.7		
U-335	1¾ x 1¾ x 3/16	3	3	10	11.5	2.2	25.4		
U-334	1¾ x 1¾ x 3/16	3	3	4	10.0	2.2	22.2		
U-333	1¾ x 1¾ x 3/16	3	3	2	9.5	2.2	21.0		
U-332	1¾ x 1¾ x 3/16	3	2	6	7.5	2.2	16.7		
U-331	1¾ x 1¾ x 3/16	3	2	4	7.0	2.2	15.5		
Weld section:									
U-300	1 x 1 x 3/16	3	10	0	30.0	1.2	36.0		
Diagonals	1 x 1 x 3/16	18	2	0	36.0	1.2	43.1		
Horizontal (top-bottom).	1 x 1 x 3/16	6	1	6	9.0	1.2	10.8	327.3	
Weight of 25-foot section									327.3
U-292	2½ x 2½ x ¼	3	5	0	15.0	4.1	61.5		
U-292	2¼ x 2¼ x 3/16	3	3	0	9.0	2.8	25.2		
U-302, U-303	2 x 2 x 3/16	3	13	9	41.3	2.5	103.0		
U-337	⅜ rod	6	8	0	48.0	0.376	18.0		
U-338	⅜ rod	6	9	0	54.0	0.376	21.2		
U-314	1½ x 1½ x 3/16	3	5	0	15.0	1.8	27.0		
U-315	1½ x 1½ x 3/16	3	6	4	25.0	1.8	45.0		
U-204, U-205	2 x 2 x 3/16	3	13	9	41.3	2.5	103.0		
U-339	⅜ rod	6	9	8	58.2	0.376	21.8		
U-340	⅜ rod	6	10	8	64.2	0.376	24.0		
U-316	1½ x 1½ x 3/16	3	7	6	22.5	1.8	40.5		
U-317	1½ x 1½ x 3/16	3	8	9	26.3	1.8	47.2		

[1] The pieces are of angle iron except as indicated.

Weight of various sections of inner tower—Continued

Plan No.	Size (inches)[1]	Number of pieces	Length		Total length	Weight per foot	Total weight	Total weight by sections	Total weight of inner tower
			Ft.	*In.*	*Ft.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
U-281 U-282	2 x 2 x ¼	3	13	9	41.3	3.2	132.0		
U-341 U-342	1¼ x 1¼ x ⅛	6	16	6	99.0	1.1	109.0		
U-318	1½ x 1½ x 3/16	3	10	2	30.6	1.8	55.0		
U-319	1¾ x 1¾ x 3/16	3	11	4	34.0	2.2	75.0		
U-283 U-284	2¼ x 2¼ x ¼	3	13	9	41.3	3.7	153.0		
U-343 U-344	1¼ x 1¼ x ⅛	6	18	2	109.0	1.0	109.0		
U-320	1¾ x 1¾ x 3/16	3	12	8	76.3	2.1	160.0	1,330.4	
Weight of 77-foot section									1,658
U-360	1 x 1 x ⅛	3	7	6	22.5	0.8	18.0		
U-283 U-284	2¼ x 2¼ x ¼	3	13	9	41.3	3.7	153.0		
U-351	2 x 2 x 3/16	3	14	0	42.0	2.5	105.0		
U-353 U-354	1¼ x 1¼ x ⅛	6	20	0	120.0	1.0	120.0		
U-352	2 x 2 x 3/16	3	15	3	45.8	2.5	114.5	510.5	
Weight of 90-foot section									2,168
U-361	1 x 1 x ⅛	3	7	6	22.5	0.8	18.0		
U-287 U-288	2¼ x 2¼ x ¼	3	13	9	41.3	4.1	170.0		
U-357 U-358	1½ x 1½ x ⅛	6	22	0	132.0	1.3	172.0		
U-355	2¼ x 2¼ x 3/16	3	16	6	49.5	2.8	138.5		
U-356	2¼ x 2¼ x 3/16	3	17	9	53.7	2.8	150.5	649.0	
Weight of 103-foot section									2,817
U-371	1 x 1 x ⅛	3	7	6	22.5	0.8	18.0		
U-287 U-288	2½ x 2½ x ¼	3	13	9	41.3	4.1	170.0		
U-367 U-368 U-369 U-370	1½ x 1½ x ⅛	6	24	0	144.0	1.3	188.0		
U-365	2½ x 2½ x 3/16	3	18	10	56.4	3.1	175.0		
U-366	2½ x 2½ x 3/16	3	20	2	60.6	3.1	188.0	739.0	
Weight of 116-foot section									3,556
U-380	1 x 1 x ⅛	3	7	6	22.5	0.8	18.0		
U-400 U-401	3 x 3 x ¼	3	13	9	41.3	4.9	203.0		
U-376 U-377 U-378 U-379	1½ x 1½ x ⅛	6	26	0	156.0	1.3	203.0		
U-374	3 x 3 x 3/16	3	21	4	63.8	3.8	242.0		
U-375	3 x 3 x 3/16	3	22	8	68.3	3.8	259.0	925.0	
Weight of 129-foot section									4,481

TOWER EXTENSION

U-362	1 x 1 x 3/16	3	10	4	31.0	1.2	37.2		
Diagonals	1 x 1 x 3/16	18	2	0	36.0	1.2	43.1	80.3	

[1] The pieces are of angle iron except as indicated.

	Actual weight
	Pounds
Observer's platform	114
Light keeper's platform	37

Combined weights of outside and inside towers

[For various heights, including observer's and lightkeeper's platforms but not including the nuts and bolts]

	Pounds
25-foot tower	1, 215
77-foot tower	4, 158
90-foot tower	5, 270
103-foot tower	6, 640
116-foot tower	8, 247
129-foot tower	10, 494
Total weight of tower extension	345

ANCHORS

Each anchor post is 5 feet long riveted to a steel footplate in which are four holes for bolting it to a wooden mudsill. The wooden mudsills are not supplied by the factory, but timbers for them can be obtained at any lumber yard. Each mudsill should be 3 inches thick, 8 inches wide, and 3 feet long. The bolts should be put through from the underside with a large washer under the head of the bolt. The wooden mudsills should be made and bolted to the footplates before the towers are sent out to the stations and need not be taken off when the towers are taken down and moved. The six crosspieces 2 by 10 by 36 inches mentioned on page 12 are also carried from station to station.

ERECTING TOWER

HOLES FOR ANCHORS

The first step is to trace the outlines of the holes for the anchors, as shown on the ground plan, Figures 3a and 3b. A stake with a nail in the top may be used for a temporary station mark from which to locate the holes. It is convenient to use a small theodolite (fig. 5) or a builder's level, and a steel tape for this work. The theodolite should be plumbed over the temporary station mark. The angle readings to the centers of the three holes are 0°, 120°, and 240°, respectively, and the distance from the center stake to each anchor post is given on the ground plan. In setting the anchors the measurements given on the ground plan corresponding to the height of tower to be erected should be used. If possible, the orientation of the tower should be such that no line of sight from the head of the inner tripod will be obstructed by a leg of the outer structure. With the aid of an azimuth compass and the progress sketch the approximate direction of each line can be determined and the holes can be located to give best clearance for the lines. The holes should be about 3 feet square and 5 feet deep. The bottoms of the holes need be only approximately on the same level, as the difference in level can be adjusted by the bolt holes in the tops of the anchor posts.

Care should be taken to get the inner and outer tower anchor posts in alignment with the station mark and to give each anchor post the same slant as the corresponding corner post of the tower.

SETTING ANCHORS

The legs of the inner tower have a different slope from the legs of the outer tower. To set the anchor posts at the correct distance from the center stake and at the proper slope a frame template is used. This consists of a 1 by 4 inch board long enough to reach from the center stake to the outer anchor post for the tallest tower. On one end of the board is nailed a 1 by 3 inch board about 3 feet long, making the same angle with the long board as the outer tower leg makes with the horizontal plane. On the other end of the long board

FIGURE 5.—Four-inch theodolite.

is nailed another 1 by 3 inch piece making the same angle with the long board as the leg of the inner tower makes with the horizontal. The long board can be marked with the distances from the center stake to the bottom of the lower tower leg for towers of different heights. If the long board is placed on the center stake, made horizontal with a carpenter's level, and held with the slope piece for the outer anchor post against that post at the proper distance from the center for the height of tower which is being erected, then the anchor post can be adjusted for slope and distance at the same time. The same process is used for the anchor post for the inner tower leg, using the other slope piece and the correct distance from the center for the inner tower as marked on the horizontal piece. The template should be so constructed that the foot of the slope piece will reach to approximately the same point on the anchor post as the bottom of the tower leg. If this is done, it will not be necessary to bend the bottom of the tower leg to fit it onto the anchor post.

If towers of 77 feet, or less, to the top of the inner tripod are built, a second template is required, since the legs of the outer tower have a different slope on the two lower sections of the 103-foot tower from that of the upper sections.

When the anchors are put in place they must be firmly settled by using a heavy ram, then by filling in dirt and tamping well to a depth of about 1 inch above the anchor timber. Then two planks, 2 by 10 by 36 inches, should be placed crosswise on top of the anchor timbers, one on each side of the steel post. The lower half of the hole can then be filled in. The dirt must be well tamped and special care must be taken that no large rock or sod forms a solid connection between the inner and outer anchor posts. A solid substance between the two anchors will transmit movements of the outer tower to the inner one and make accurate observations impossible.

LEVELING TOWER

After the anchors are set and holes are about half filled, a round of levels should be taken to determine the place on each post at which each leg of the lower tower section should be fastened to insure that the tower will be plumb. As shown on the working plans (fig. 2), there are 14 bolt holes 1 inch apart in the upper end of each anchor post. A bolt should be placed in a hole of one anchor post and used for a bench mark. The instrument should then be leveled over the center peg and a leveling rod consisting of a piece of 1 by 4 inch board should be set on the bolt and the height of the instrument marked on it. By holding this rod beside each of the other posts and sliding it up or down until the mark is again at the height of the instrument, the bottom of the rod will show which hole is at the same height as the bolt in the first post and a bolt can be placed in this hole. The lower section of the tower can then be bolted on, care being taken to use the proper hole in each anchor as indicated by the levels.

The small theodolite used for locating the anchor holes can be used as a leveling instrument by setting the vertical circle to the reading corresponding to the horizontal position of the telescope and then bringing the bubble to the center of the tube by means of the vernier slow-motion screw.

ERECTION OF TRIPODS

Both inner and outer towers are built up in sections of 13 feet 8 inches, which is the length of one piece of each corner post. The members of the inner and outer towers are marked with paint of contrasting colors, as described on page 3. Each section has two sets of horizontal members and one set of diagonal braces as shown on the working plan. (See fig. 2.) The horizontal members are spaced 6 feet 10 inches apart. Figures 6 and 7 show the first section of the tower completed and the second section under construction. Three men work aloft and one man on the ground sends the pieces up as needed, using a single 6-inch ball-bearing pulley and half-inch rope. After the two lower sections are built, the individual pieces are sent up on a rope which passes through the upper pulley and the loose end of which is wound around a detachable drum secured to the rear wheel of a jacked-up truck. With this arrangement the hauling up takes very little time compared to sending these pieces up by hand.

The pieces for the corner posts are sent up first, piece by piece, and bolted in place. Then one set of horizontal ties is sent up and bolted on. Next the diagonal braces are sent up. The lower ends are bolted to the corner post, and near the intersection of the two diagonals they are bolted to the horizontal tie. This completes the lower part of the section. Then the small platform at each corner of the inner tower on which the workman stands is placed in a corresponding position on the horizontal members above. From there the top set of horizontals and the top ends of the diagonals are bolted to the corner posts and the platform is again raised.

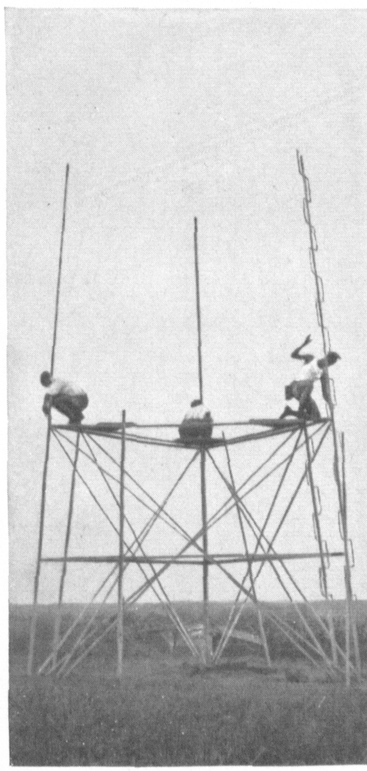

FIGURE 6.—Lower section of tower completed, corner posts being bolted on for second section.

The inner and outer towers are built up together to within one and one-half sections of the observer's platform. On a 90-foot tower this is to the top of the fifth section. Then the outer tower is completed, including the observer's platform. The observer's platform is in three sections and the center section is the first to be sent aloft. When the outer tower is completed the hauling line is then dropped down through the center and the block made fast to the top of the outer tower.

The two top sections of the inner tower are then put in place. The welded 10-foot upper section of the inner tower is, of course, always transported and erected as a unit. The next lower section is also usually kept bolted together and is erected as a unit. Each is so designed as to permit being hoisted through the inside of the next lower section.

CONSTRUCTION PLATFORMS

The small platforms mentioned above are of great importance, for upon the proper construction and use of these platforms depends the safety of the men working aloft. Three of these triangular platforms are needed, one for each of the inner corners of the tower. They are about 24 inches on each side, with 2- by 2-inch cleats nailed on the under side to fit closely along the outside of the horizontal ties on which the platform rests. Each workman must be cautioned to make certain that the platform is securely in place before trusting his weight upon it. In a strong wind the platform may be lifted out of position without the workman noticing it. Under conditions of high winds a couple of strong spring clips should be fastened to the under side of each platform in such position that one end of each clip can be slipped under the flange of the horizontal steel piece on which the platform rests to hold the platform securely in position.

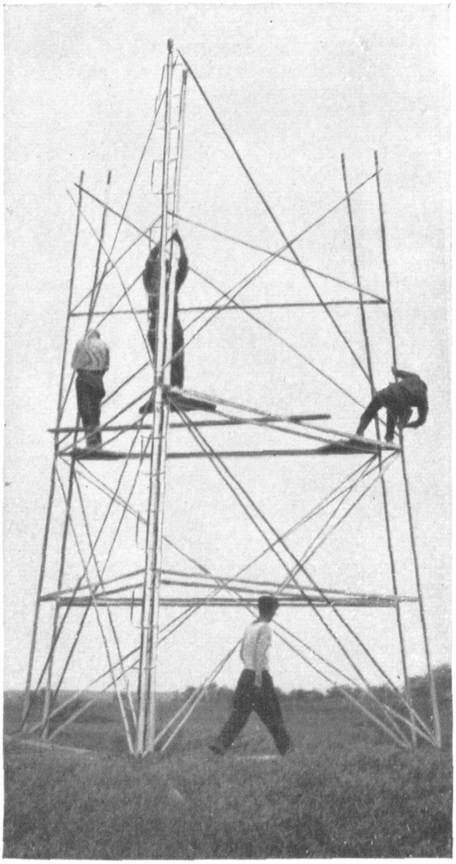

FIGURE 7.—Work on second section of tower.

MARKS FOR TRIANGULATION STATIONS

The essential parts of the specifications for station and reference marks now in use are given below:

Metal tablets.—Each station which has been located with first, second, or third order accuracy, should be marked by a standard tablet of copper alloy, so fastened in the rock or concrete as to effectively resist extraction, change of elevation, or rotation. (See fig. 11.) The name of the station and the year established should be stamped upon the mark, preferably before it is set in the rock or concrete.

Setting of tablets.—Stations for horizontal control must often be located where the permanent marking of them is difficult, and for that reason a great variety of settings for the tablets must be permitted. The location of the station, depth of soil, or presence of rock ledges, and the availability of materials will usually control the choice of the mark to be used. The precautions to be taken in establishing each kind of mark are briefly stated below.

(1) *In rock outcrop.*—Care should be taken that the rock in which a mark is set is hard and is part of the main ledge, not a detached fragment. The tablet should be countersunk and well cemented in.

(2) *In boulders.*—When a tablet is set in a boulder, the latter should be of durable material and of cross section, area, and depth below the surface not less than the standard concrete mark as described below.

(3) *In rock ledges below surface.*—When the ledge is only slightly below the surface, a tablet set in the usual manner in the ledge will be sufficient, provided two reference marks are established. Where the ledge is so far below the surface that a surface mark is required, a tablet or copper bolt should be set in the ledge, the ledge carefully brushed or washed off for a space at least 18 inches in diameter, and a concrete surface mark placed above the subsurface mark. A tablet should

be set in the surface mark directly over the subsurface tablet or bolt. If the rock ledge in which the subsurface mark is set is very smooth, it should be furrowed with a chisel to afford better anchorage for the concrete.

(4) *In concrete*—(*a*) *Shape.*—The mark should be either a frustum of a cone or of a pyramid, or have the form of a post with an enlarged base. If of pyramidal or conical form, the sides should have a batter of at least 1 inch to 1 foot. When a post with an enlarged base is used the bottom of the base should be 4 inches larger in least horizontal dimension than the post proper and should have a vertical thickness of at least 6 inches. If the concrete is cast in place the enlarged base can easily be provided for by enlarging the bottom of the hole at the sides with the digger. Extreme care should be used to avoid making the mark with a mushroom top or with projecting corners near the surface, which would provide leverage points for frost action and would make easier the malicious destruction of the mark.

(*b*) *Size and depth.*—The concrete post should extend to a depth of from 30 to 36 inches, depending upon the kind of soil. It should be not less than 14 inches in diameter, except that the upper 12 inches may be in the shape of a frustum of a cone or pyramid with the upper surface not less than 12 inches in diameter. Where the mark is not in the path of traffic or in soil subject to cultivation, it should extend from 2 to 4 inches above the surface. If located where traffic passes over it the top of the mark should be slightly below the surface.

Before sending the towers out at the beginning of a season a set of forms should be made for the station and reference marks and sent out with each tower. When the tower is taken down and moved, the concrete in the marks will be set and the forms can be taken off and sent forward with the tower so as to be ready for use at the next station. If care is taken in removing the forms, they can be used during an entire season's work. The lumber for a set of forms costs $1.75, and it requires one hour for one man to make one set of forms. While this is a small item, it will amount to about $60 per month, aside from the time saved in going after lumber, and is well worth considering.

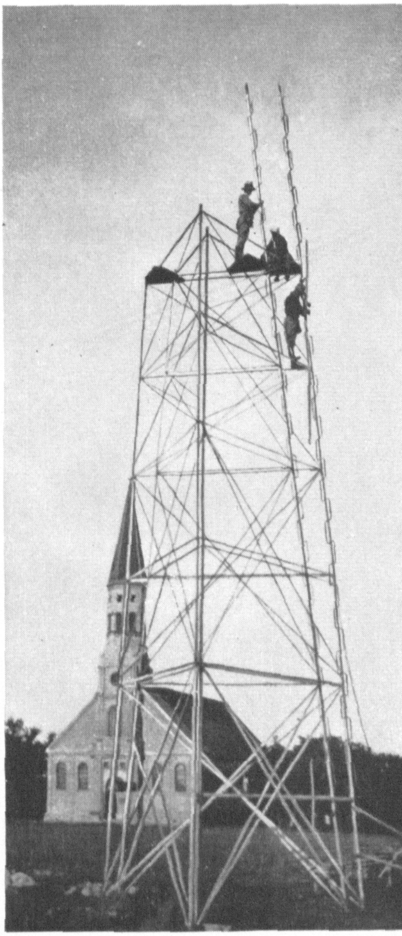

FIGURE 8.—Corner posts being bolted on fourth section of tower.

The procedure in making the standard concrete mark is as follows: A hole is dug to a depth of 3½ feet or more. It should be 16 inches in diameter for the top 2½ feet and 10 inches in diameter at the lower end. Concrete made of good cement, sand, and gravel or broken rock is placed in the lower part of the hole to a depth of 6 inches. A standard tablet station mark (fig. 11) is then set in the concrete, with the top of the tablet slightly depressed. This completes the underground mark. A layer of 4 to 6 inches of sand or dirt is then put into the hole. The hole is then enlarged about 2 inches in radius near the bottom in order that the lower end of the block of concrete for the surface mark will be mushroomed, and then the hole is filled with concrete to within 9 inches of the surface of the ground. Next a mold or frame 12 inches on a side at the top, 13 inches at the bottom, and 12 inches in depth is set in the hole on top of the concrete and filled in around the outside with dirt tamped firmly. The frame is then filled with concrete level with its top and a standard tablet station mark (fig. 11) is set in the center of the concrete, with the top of the tablet slightly depressed. The tablet must be centered exactly over the underground mark. The top of the concrete should be smoothed with a trowel and the frame should be left in place to protect the concrete until it becomes firmly set.

Care must be taken not to disturb the position of the tablet in the underground mark when placing the layer of sand or dirt and when pouring the concrete for the surface mark. A piece of thin board should be placed over the lower mark or other suitable means used to insure against any horizontal movement of the tablet due to the impact or pressure of the material above.

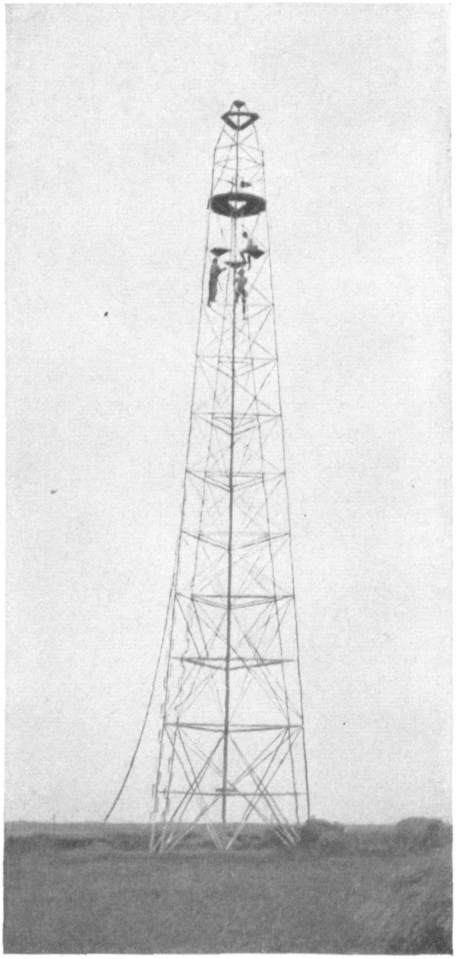

FIGURE 9.—Outer structure complete; top section being bolted on inner structure.

SPECIAL CONDITIONS

Under certain conditions special marks will often be required, and these should conform in size and durability to the marks described above.

(1) **Sand.**—In sand, which if used as a mold would spoil the concrete by absorbing the water from it, sewer tiles 8 inches in diameter and 30 inches long may be used, set with the bell end down, filled with concrete and with the base end set in concrete. A sheet-iron mold of the same dimensions filled with concrete may also be used. A metal tablet should be set in the center of the top.

(2) **Marsh.**—Where the surface of the ground is too soft to hold a mark of the usual type, a post of durable wood should be forced down vertically as far as it will go, its top cut off flush with the surface, and a sewer tile at least 6 inches in diameter set into the marsh around the top of the post. The tile should then be filled with concrete and a tablet set in the top. Where the marsh is very soft but dries out at certain seasons of the year, successive tiles can be forced down around the post, the post then can be withdrawn and the mud worked out from within the tiles, and the tiles then filled with a hydraulic cement mixture.

(3) **Land subject to cultivation.**—The subsurface or lower mark should be a tablet in a block of concrete 10 inches square or 10 inches in diameter and 6 inches thick, set with its top 3 feet below the surface. The upper mark should be a tablet set in a block of concrete 15 inches in least horizontal cross-section dimension and 20 inches high, with its top 12 inches below the surface of the ground. About 3 inches of dirt should be placed between the concrete blocks bearing the upper and lower marks.

All stations so marked should be referenced by two or more standard reference marks placed on property boundary lines, preferably along a well-established highway or quarter-section line, in a location where there is little likelihood of their being distubed. The directions to the reference marks should be such as to give a good angle of intersection at the station. The reference marks may be as much as a half mile from the station, if necessary, provided they can be seen from the station. The distance to each reference mark should be carefully measured. Other distances, such as those to the center of a highway, the corner of a building, or the center of a well, should be measured if feasible. Two or more such measurements will intersect so near the station that the concrete block will be easily found with a small prodding rod. When measurements are made to buildings or other objects the directions must also be given. If measurements of this kind are made the station may usually be easily recovered, though the reference marks may both be destroyed. The measurements to a road should always be to the center of the road and not to the fence line. All distances must be carefully measured and not estimated. Care should be taken in placing reference marks along highways, for nearly all States are widening the highways.

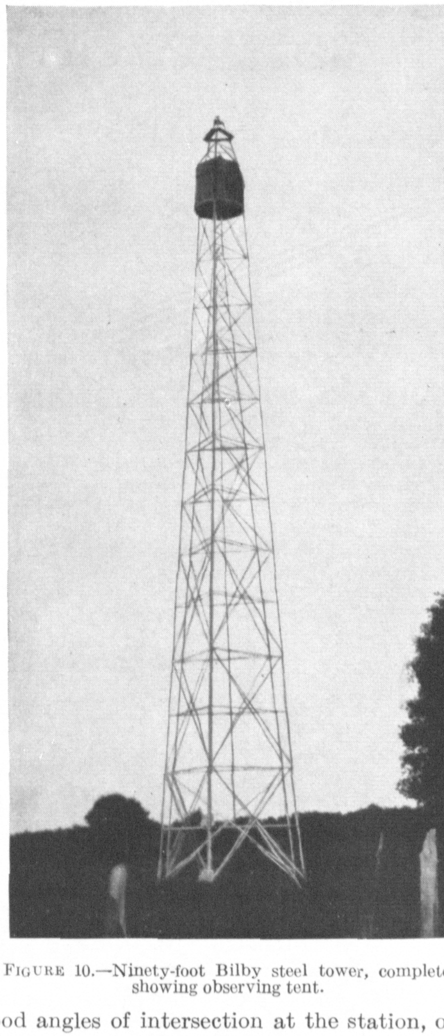

FIGURE 10.—Ninety-foot Bilby steel tower, complete, showing observing tent.

REFERENCE MARKS

Each reference mark should consist of a metal tablet similar in material and shape to the station mark, but bearing an arrow which points to the station. A reference mark should be stamped with the same designation as its station mark, and where there is more than one reference mark they should be numbered serially in a clockwise direction, the number to be stamped upon each one. Each should be set under the same conditions as specified for the station mark, except that the concrete post in which it is set may be 2 inches smaller in diameter and 6 inches shorter than for the station mark.

Each station mark must have at least two reference marks. If the station mark, due to surface conditions, is entirely beneath the surface, there should be three reference marks, unless there are permanent witness marks, such as road crossings, etc., which will serve to locate the station without an excessive amount of digging. If the station mark is on ground liable to be disturbed or washed away, three reference marks should invariably be established. These should be so located as to avoid the probability of both being disturbed by the same cause. They should also preferably be so located as to give good angles of intersection at the station, or else be placed on ranges with the station.

Material.—The main considerations in making concrete are to have clean materials, mix them well before adding water, have the mixture not too wet, and tamp well into the form. Each streak of dirt in concrete means a line of cleavage. Where rough aggregate is available the proportions may very well vary from 1–2–4 to 1–3–5, but the top 12 inches of the mark should be of considerably richer mixture. Where only cement and sand are available the lower part of the mark should be proportioned 1 part of cement to 3 parts of sand, and the upper part should be 1 part of cement to 2 parts of sand. With a mark of the proper size it will not be necessary to reinforce the concrete with metal

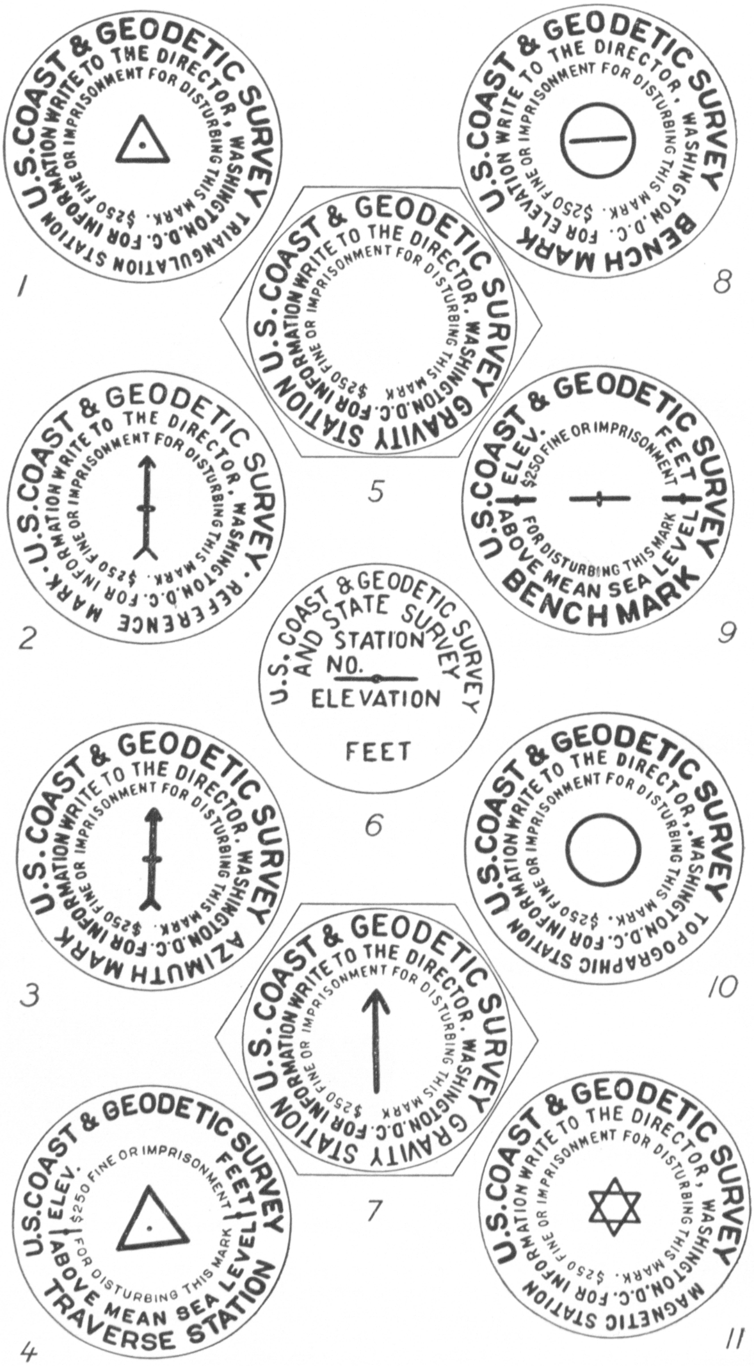

FIGURE 11.—Standard marks of the U. S. Coast and Geodetic Survey.

1. Triangulation station mark.
2. Reference mark.
3. Azimuth mark.
4. Traverse station mark.
5. Gravity station mark.
6. State Survey mark.
7. Gravity reference mark.
8. Tidal bench mark.
9. Geodetic bench mark.
10. Topographic station mark.
11. Magnetic station mark.

rods or wire. To avoid cracking of the concrete, due to rapid drying, it should be covered with paper or cloth and then with earth or other material for a period of at least 48 hours.

AZIMUTH MARK

At stations where a tall tower is used to render adjacent stations visible, the observing party is instructed to measure the direction to some nearby permanent object which is visible from the ground at the station, in order that surveyors using the station after the tower is removed may be able to obtain an azimuth, or direction, as well as a geographic position. An azimuth mark must be established at least ¼ mile from the station and in a location where it will be visible through an instrument mounted over the mark on a surveyor's ordinary tripod. When an azimuth mark is established only two additional reference marks are needed. (See above.)

TRAVERSE STATIONS

The size and character of the mark at traverse stations should be the same as for triangulation stations, except that certain stations may be left without permanent marks when several are close together. The following rules will apply to the distribution of permanent marks on first-order traverse.

In general, there should be a permanently marked station at least every 2 miles along the traverse. A traverse station should always be permanently marked if either of the lines leading from it is a mile or more in length. When a station is marked in a permanent manner, one of the adjacent stations must be permanently marked in order that a line of known length and direction may be recoverable. Traverse stations which are not marked permanently should be marked by stakes of some durable wood in order that they may be recoverable for at least a few years.

Reference marks should be established only in special cases. They should be used when the station mark is entirely beneath the surface of the ground and there are no permanent witness marks near it such as road crossings, etc. Reference marks should be set if the station is at a railroad crossing or junction point or if both of the adjacent stations are 4 or 5 miles distant. In cases where reference marks are required, two should invariably be established for each station. They should be so located as to avoid the probability of both being disturbed by the same cause. Along a railroad track they should usually be placed in the fence lines of the right-of-way, and on opposite sides of the track. They should be so located as to give a good angle of intersection at the station or else be in range with the station. Traverse stations along a beach which are subject to loss by the erosion of the shore line should have two reference marks placed as far back from the shore line as practicable.

Whenever a horizontal control mark is to serve also as a bench mark it should correspond in depth below the surface to the requirements for bench marks. (See Spec. Pub. No. 140, p. 31.)

VERTICAL COLLIMATOR

An instrument called a vertical collimator is used for centering a tower over the mark of a previously established station, for placing a mark under a new tower, or for centering the theodolite or lamp over the station mark.

The type of collimator shown in Figure 12 consists of a right-angled telescope, the objective end of which is mounted vertically in a bracket collar which is supported by a tribrach with three leveling screws. The vertical element of the telescope can be rotated in its collar through an angle of somewhat more than 270°, which permits the cross hairs mounted on the diaphragm of the right-angled eyepiece to be adjusted to the optical axis of the telescope. A level bubble is attached normal to the vertical element of the telescope and revolves with it. The bubble and the cross hairs are tested and adjusted in the usual manner.

The collimator is so constructed that it can be mounted on an ordinary theodolite tripod. The tripod should have an adjustable head which will permit of some horizontal motion of the instrument on the tripod head to facilitate plumbing the instrument over or under a definite point.

To determine a point on the ground directly beneath the hole in the cap plate of the light stand set up the collimator on its tripod approximately in its correct location, adjust and level the collimator, and attach the plumb bob. By sighting upward at the hole in the cap plate a close estimate can be made of the distance the tripod must be moved to place the collimator directly beneath the hole in the cap plate. A piece of board may be placed on the ground beneath the plumb bob and the point for the new trial centering of the collimator marked on the board. The tripod is then shifted and centered roughly by the plumb bob over the new trial point and the instrument accurately leveled. Usually the final adjustment into the vertical line through the hole in the cap plate can now be made by shifting the adjustable tripod head.

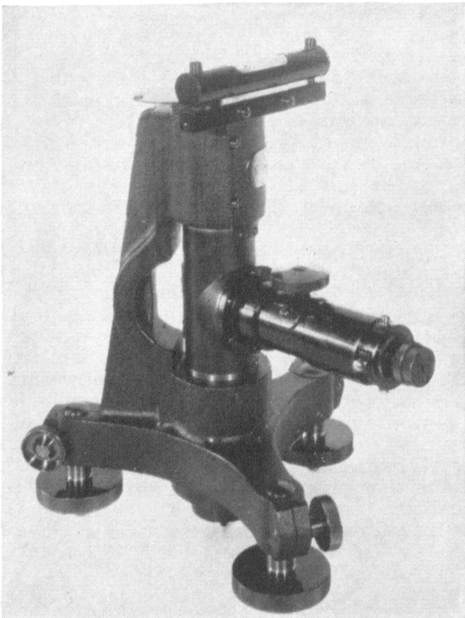

FIGURE 12.—Vertical collimator.

A bench is now built without disturbing the collimator, and the exact point on the bench is determined by means of the plummet attached to the collimator. The bench can be made by driving two stakes about 4 feet apart, one on each side and in line with the center stake. Place a 1- by 4-inch board across the top of the stakes, then nail to this board another piece about 12 inches square directly over the center stake. Drive a nail through one end of the 1- by 4-inch board into the stake at that end, and at the other end drive a nail about ½ inch into the stake. The latter end can then be moved to one side when necessary and can be replaced exactly in its original position at any time.

To center the hole in the cap plate of the light stand directly over the station mark set up the collimator directly over the mark, adjust and level it. Move the cap plate until the hole marking the center is directly in line with the vertical line of sight and then clamp the plate to the horizontal members at the top of the outer tower.

USE OF THEODOLITE IN PLACE OF COLLIMATOR

If a vertical collimator is not available, the centering can be done with a theodolite or transit. The instrument should first be put in as nearly perfect adjustment as possible. The objective should be focused until there is no parallax or apparent movement of the intersection of the wires over an object on which it is pointed when the eye is moved back and forth in front of the eyepiece. The stride level should be carefully adjusted. The instrument should be set up at a distance from the tower about equal to the height of the tower and leveled up by using the stride level. Of course, if a transit is used, the leveling must depend upon the plate levels. A pointing should be made upon the center of the tripod head, using the slow-motion screw, and then the telescope should be plunged down to point to a piece of horizontal board placed on the ground under the tripod. Two marks should be made on this board, one near the side toward the instrument and one near the far side, both coinciding with the line of sight of the instrument. The telescope should then be reversed, the instrument rotated 180° around its vertical axis, a pointing made on the center of the tripod head, and the telescope again plunged down to point to the board. If the line of sight is now slightly to one side of the two marks on the board, due to a lack of perfect adjustment of the instrument, two more marks should be made on the board beside the first two to define the second line of sight. A line should then be drawn on the board to give the mean position of the two lines of sight. The theodolite should then be moved to a point about 90° around the tower and the whole process repeated. The intersection of the two lines will be the point sought. If the mark is already established, a similar process can be used to plumb up to the tripod head.

DISMANTLING TOWERS

The towers are taken down by reversing the order of the operations used in their erection. Each part of the inner structure is marked with a band of red paint and each part of the outer structure with a band of blue, thus making it easy to separate the parts for each structure. As the tower is taken down the rods and crossbars of each section are wired together with No. 14 stovepipe wire. The upper two sections of the inner tower are lowered, then the work starts at the top of the outer tower and continues downward. The lower sections of the inner and outer structure are taken down, section by section. After the anchors have been taken out, the holes must be filled, well tamped, and rounded up to allow for settling, in order that the ground may be left in good condition.

ORGANIZATION OF PARTY

The organization of parties and the manner in which the work is carried on are as follows:

One chief of party may have charge of both the tower-building and the observing parties and have a signalman or foreman hand to superintend the building. The construction party should consist of 3 subparties—2 advance parties of 4 men each and 1 rear party of 4 men. One man of each subparty acts as foreman. Attached to the construction party are two men, each with a truck and trailer, with which to move the towers forward. Each subparty must be provided with a truck as a means of transportation, and with necessary tents, tools, instruments, and equipment. The signalman or foreman hand in charge of the construction must also be provided with a truck, lamps, heliotropes, and other equipment for testing lines.

As soon as the observations on one or more of the rear towers are finished, the chief of the observing party will notify the rear construction subparty which takes the towers down. Usually the notification will be made through the rear light keeper, by code signals. With two observers, one on each side of the scheme, usually two towers are ready to be taken down on the same day. Therefore as soon as the rear construction subparty has taken down one tower it moves across the scheme to the second tower and takes it down also. Then the material of each complete tower is loaded on one of the trailer trucks and moved forward to the site of a new station, where one of the advance subparties will reerect it. Each forward subparty carries an extra set of anchors and as soon as it reaches the site of a new station the men dig holes and set the anchors, so that usually everything is in readiness to begin erecting the tower as soon as it arrives.

For a double observing party there should ordinarily be 12 towers, 8 of which will usually be standing while 2 towers at the rear are being taken down and 2 at the forward end are being erected at new stations.

Under certain conditions it is necessary that the two advance subparties should have one or more additional men to assist in digging holes. In localities where extra labor can be employed the chief of the construction party can go ahead, mark out positions for the holes, and employ the necessary men to dig the holes and have them ready for the anchors when the construction party arrives.

A party organized as described in the preceding paragraphs can take down, move, and erect an average of 30 towers per month if the observing party is not seriously delayed by bad weather.

Care should be taken in selecting for the building party men specially fitted for the work. Men working aloft should be from 5 feet 10 inches to 6 feet in height, should weigh not more than 170 pounds, and should not be more than 35 years of age. They should be of the athletic type and not given to talking while at work, except when they have something important to say. The two men for the trucks used in moving the towers must be careful drivers and good mechanics who can keep their trucks in good order. They must be men who can find their way through new country and who will cooperate with the building parties. Usually the truck driver is at the rear when a tower is being taken down and should assist in that work. In return, the forward and rear subparties should assist the truck driver in loading and unloading. It is teamwork that makes the work move along smoothly. When any member of a party becomes grouchy and does not show a proper disposition to cooperate with other members of the party, it is advisable to displace him.

As it is often necessary for the parties to move at night, each truck should be provided with a good lighting system.

COOPERATION OF THE BUILDING AND OBSERVING PARTIES

The officer in charge of building should camp in some large town about 75 miles ahead of the observing parties, where he can visit his two forward subparties and also be in touch with his truck drivers who are hauling the steel towers up from the rear. The chief of party, who is with the main observing party most of the time, can then be familiar at all times with the location of the officer in charge of building and can reach him by telephone or telegraph, in case obstructed lines or other troubles are encountered when the stations are occupied. On a combined building and observing party it is quite necessary that the foreman or officer in charge of all building operations shall return each day to his temporary headquarters, and he should arrange for someone to receive all messages and phone calls in order that the chief of party as well as each of his foremen and truck drivers may communicate with him.

LOCATION OF STATION

The station is often located on or near the fence line on the side of a public highway. Often a telephone line is along the same side of the highway. In building the tower the telephone wires can pass through or along the side of the tower but they should not touch the inner tower. If the wires come near or touch any part of the outer tower, a few layers of old inner tire tube should be placed between the wire and the tower. In this way the telephone wire can be made fast to the outer tower if necessary to prevent it from touching the inner tower. The towers are also easily put up among trees without any clearing or cutting of limbs.

SECURING AUTHORITY TO ESTABLISH STATIONS

It shall be the duty of the officer in charge of the building to obtain the permission of the property owners before a mark is set and the tower erected. The regulations state that settlement may be made for damages incurred in cutting trees or destroying crops, provided a written agreement is made with the landowner before the damage is done. It will usually be found to be the case that, if the purpose of the survey is explained to the property owner beforehand, permission will be granted and no damages will be claimed. If damages are claimed, the amount must be determined beforehand on a basis of the value per acre of actual damages to crops or the unit value of injuries to trees. If crops are damaged, the area involved should be measured and the damages computed, using the value per acre agreed upon. Usually the amount is so small that the property owner does not insist on payment. If trees are cut it is very essential that the *amount of damages be agreed upon beforehand. Under no condition* should a station be established without interviewing the property owner and arriving at a basis of settlement. Much trouble has been caused in the past by carelessness in this respect.

The chief of party should instruct all employees that, if any property owner discusses the matter of damages, they should tell him that actual damages only can be paid and that payment can only be made in the event of a prior agreement.

EQUIPMENT FOR BUILDING PARTY

The following is a list of articles required for the different units of the party.

Outfit for forward building subparty of four men

Item	Number
Anchors, extra for tower, set	1
Axe, small	1
Axes, large	2
Bedding	(1)
Bits, assorted	5
Block, 6-inch single	1
Board, scaffold, 2 by 10 inches by 12 feet	1
Boards, scaffold, special triangular	3
Box, concrete mixing	1
Brace, carpenter's	1
Buckets	2
Cans, 10-gallon, water	4
Can, oil	1
Canteens	2
Chisel, cold	1
Collimator, vertical	1
Compass, azimuth	1
Cots	4
Dies, stamping, set of letters and figures	1
Digger, post-hole	1
Drills, stone	6
Emery wheel, large	1
Hammers, claw	2
Hammer, blacksmith's	1
Hatchet	1
Heliotrope	1
Lanterns, oil	3
Lamp, signal	1
Level, carpenter's	1
Line, hauling, ½-inch rope 230 feet long with stray line 8 feet long spliced to main line	1
Mattock	1
Mess outfit, including all cooking utensils	1
Picks	3
Pliers, wire	3
Plummet	1
Pockets, canvas, for nuts, bolts, and wrenches, with belts	4
Punches, special tower	4
Saws, hand	2
Saw, keyhole	1
Shovels	3
Spades, regular	2
Spades, tile	2
Square, 2-foot	1
Strap, leather, 18-inch with rings to serve as bridle between the two parts of the hauling line just above the stray line	1
Strap, rope	1
Stove, 3-burner Kamp Kook	1
Table, camp-made	1
Tape, steel, 30-meter	1
Tarps, bed	4
Telescope, draw	1
Template for setting anchors	1
Tent, 7 by 7 foot center pole	1
Tents, 9 by 9 foot center pole	2
Theodolite	1
Towels, etc	(1)
Trowel	1
Truck, 1 to 1½ ton, complete with tools and tarpaulin	1
Washbasins	(1)
Wrenches, open end for tower	4

Outfit for rear dismantling subparty of four men

Item	Number
Axe, small	1
Axes, large	2
Bedding	(1)
Bits, assorted	5
Block, 6-inch single	1
Board, scaffold, 2 by 10 inches by 12 feet	1
Boards, scaffold, special triangular	3
Brace, carpenter's	1
Buckets	2
Can, 10-gallon, water	1
Can, oil	1
Canteens	2
Chisel, cold	1
Cots	4
Dies, stamping, set of letters and figures	1
Drills, stone	2
Emery wheel, large	1
Hammer, claw	1
Hammer, heavy	1
Hatchet	1
Lanterns, oil	2
Line, hauling, ½ inch rope 230 feet long with stray line 8 feet long spliced to main line	1
Mess outfit, complete, including all cooking utensils	1
Pick	1
Pliers, wire	3
Pockets, canvas, for bolts, nuts, and wrenches, with belts	4
Punches, special tower	2
Saw, hand	1
Shovels	3
Spades, regular	2
Stove, 3-burner Kamp Kook	1
Strap, leather 18-inch with rings to serve as bridle between the two parts of the hauling line just above the stray line	1
Table, camp-made	1
Tarps, bed	4
Telescope, draw	1
Tent, 7 by 7 foot, center pole	1
Tents, 9 by 9 foot, center pole	2
Towels, etc	(1)
Truck, 1 to 1½ ton, complete with tools and tarpaulin	1
Washbasins	(1)
Wire, No. 14 gauge, soft stovepipe, bundle	1
Wrenches, open end for tower	4

[1] As needed.

Outfit for truck driver moving towers[2]

Axe	1	Rope, tow	1
Bucket, gasoline	1	Shovel	1
Bucket, water	1	Tarp, truck	1
Can, oil	1	Tarp, bed	1
Cot	1	Tent, 7 by 7 foot, center pole	1
Hammer	1	Truck, 1½-ton, with trailer, with tools and equipment complete	1
Lantern, oil	1		
Rope, lash	1		

[2] This truck driver is either on the road or with the forward or rear building parties, and therefore he does not need a camp outfit other than as mentioned in this list.

TRUCK FOR TRANSPORTING TOWERS

Figure 13 shows the type of trailer truck used for transporting the steel towers. The truck has a capacity of 1½ tons. The trailer is two-wheeled and is capable of transporting under adverse road conditions a load of 3 tons in addition to the body weight. The frame of the trailer is of steel construction, and is attached to the truck chassis so as to permit the rear wheels of the truck to pass under the frame of the trailer. The body of the trailer is 16 feet long and 5 feet wide, both inside dimensions. Brakes are provided for both the truck and trailer actuated with one operation of the foot pedal in the driver's cab. The trailer truck constitutes the most important transportation unit on the triangulation party, and it is essential that it be constructed of the best of materials and with the best of workmanship.

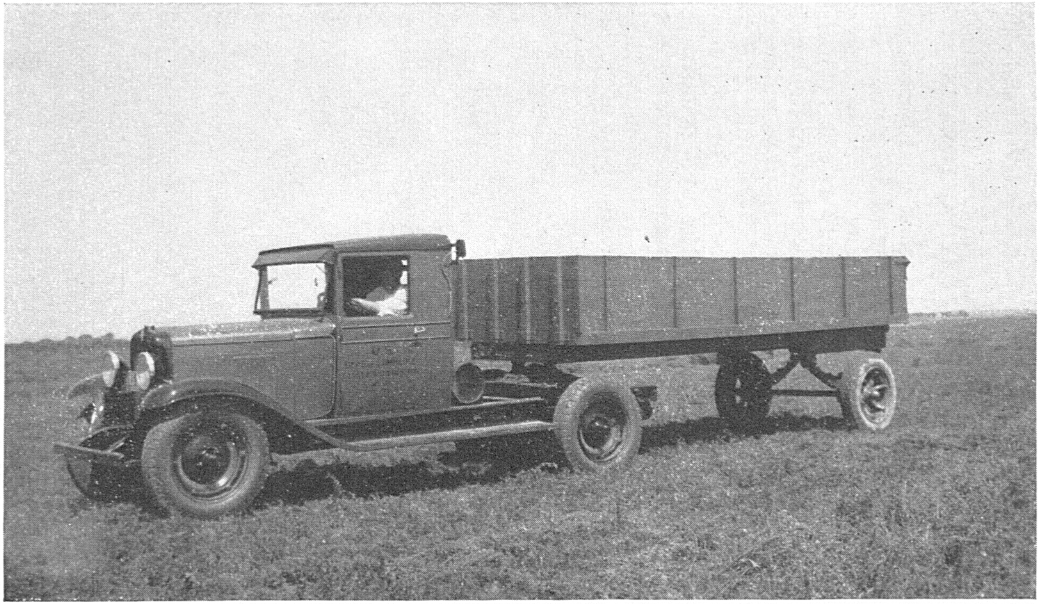

FIGURE 13.—One-and-one-half-ton trailer truck used in transporting towers.

CUT ALONG THIS LINE

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